

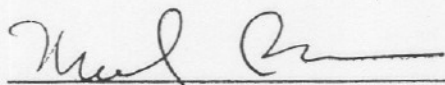
**Mission Need Statement
for the
MINERvA Project**

Non-Major Systems Acquisition

November 2005

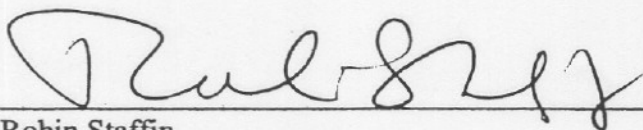
**Originator: Robin Staffin
301-903-3624
Associate Director of the Office of Science
for High Energy Physics**

CONCURRENCES:



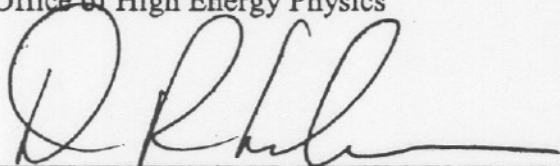
Michael Procario
Program Manager
Office of High Energy Physics

6/19/2006
date



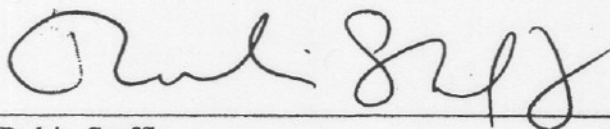
Robin Staffin
Acting Director, Facilities Division
Office of High Energy Physics

6/18/2006
date



Daniel R. Lehman
Director, Office of Project Assessment
Office of Science

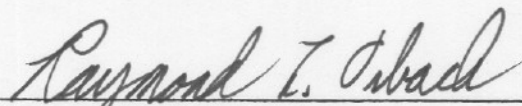
6/19/06
date



Robin Staffin
Associate Director
Office of High Energy Physics
(Acquisition Executive)

6/19/06
date

APPROVED:



Raymond L. Orbach
Under Secretary for Science

6/23/06
date

Mission Need Statement for the MINERvA project

Office of High Energy Physics
Office of Science

SYSTEM POTENTIAL: Non-Major System

A. Statement of Mission Need

The mission of the High Energy Physics (HEP) program is to explore and to discover the laws of nature as they apply to the basic constituents of matter and the forces between them. The core of the mission centers on investigations of elementary particles and their interactions. The least well understood of the known elementary particles are the neutrinos.

Perhaps the most significant development in particle physics in the last several years is the discovery that the three known types of neutrinos mix with one another. The results of a number of experiments together provide convincing evidence for neutrino oscillations, a quantum mechanical phenomenon in which neutrinos of one type turn into neutrinos of another type.

A variety of experiments are currently being conducted including the Mini-Booster Neutrino Experiment (MiniBooNE), the Main Injector Neutrino Oscillation Search (MINOS), and the from KEK to Kamioka (K2K). In addition, two experiments are being planned, the Electron neutrino Appearance experiment (EvA) and from Tokai to Kamioka (T2K) to study neutrino oscillations around the world. All of these experiments will use neutrinos with energies from about 0.5 GeV to around 3 GeV, since neutrinos with these energies provide the largest oscillation effects.

The probability that a particle interacts in a particular material is called a cross section. The cross section for a particle varies as a function of beam energy and has been measured and published. However, the cross sections for low energy neutrinos (below 10 GeV) are difficult to measure and have not been studied with any reasonable accuracy.

Improved knowledge of the cross sections will provide smaller systematic uncertainties on the oscillation measurements. Measurement of these cross-sections provide better understanding of how to determine the neutrino energy in observed neutrino events and how to reject background processes that can mimic oscillations signals.

The Main INjector ExpeRiment v-A (MINERvA) project is the fabrication a high resolution neutrino detector capable of distinguishing explicit final states in the energy range of 0.5 to 3.0 GeV and measuring their neutrino cross-sections. It supports the Department of Energy's Science Strategic Goal within the Department's Strategic Plan dated September 30, 2003: *To protect our National and economic security by providing world-class scientific research capacity and advancing scientific knowledge.* Specifically, it will support the two Science strategies: *1. Advance the fields of high-energy and nuclear physics, including the understanding of ... the lack of symmetry in the universe, the basic constituents of matter...* and *7. Provide the Nation's science community access to world-class research facilities....*

B. Analysis to Support Mission Need

Neutrinos very rarely react with matter as they pass through it. For example, a neutrino with energy of about 1 GeV would go through a stack of steel that measured the distance from here to the moon before it interacted. The interaction probability increases for higher energy neutrinos, and the best data on neutrino cross sections so far has been measured for the neutrinos with the beam energies of 100 GeV or higher.

The joint study on neutrinos by the American Physical Society discussed the importance of improved cross section measurements:

*"The precise determination of neutrino cross sections is an essential ingredient in the interpretation of neutrino experiments and is, in addition, capable of revealing exotic and unexpected phenomena, such as the existence of a neutrino magnetic dipole moment. Interpretation of atmospheric and long-baseline accelerator-based neutrino experiments, understanding the role of neutrinos in supernova explosions, and predicting the abundances of the elements produced in those explosions all require knowledge of neutrino cross sections. New facilities, such as the Spallation Neutron Source, and existing neutrino beams can be used to meet this essential need."*¹

Alternative 1

The NuMI (Neutrinos at Main Injector) facility at Fermilab delivers the most intense neutrino beam in the world to the MINOS experiment which currently is in operation to study neutrino oscillation. To maximize the observation probability of neutrino oscillation in the MINOS Far Detector, located in northern Minnesota, the NuMI facility produces the low energy neutrinos in the 1 to 5 GeV range. However, the MINOS detector can not measure the neutrino cross sections because it can not identify the complete set of particles produced in a neutrino interaction.

¹ <http://www.aps.org/neutrino/>

This NuMI beam can be enhanced with a relatively small and inexpensive detector that has higher detection sensitivities to the particles produced in a neutrino interaction. It will provide high quality cross section data.

Alternative 2

There are no other existing neutrino beams which produce neutrinos at the same energy. A neutrino beam could be constructed at another high intensity proton accelerator, such as the Spallation Neutron Source. This would incur additional costs (~\$200M) for the construction of the neutrino beam and perhaps a detector hall. It would also disrupt operation of that facility.

C. Importance of Mission Need and Impact If Not Approved

The MINERvA project is part of a program to understand neutrino oscillations and to study the lack of symmetry (CP violation) in the universe. The Department of Energy (DOE) strategic goal to advance scientific understanding includes a strategy to study the lack of symmetry in the universe. The study of CP violation falls under this strategy. Since the discovery of CP violation in 1964, it has been an important component of the DOE HEP program with the Stanford Linear Accelerator Center (SLAC) B-Factor being the most recent large scale facility to address it.

The only alternatives to the MINERvA project are basically to rely on near detectors to provide an appropriate normalization for neutrino oscillation measurements. The calculation of oscillation parameters from near and far detectors does cause many systematic effects to cancel. However, there are limits to this technique and MINERvA is designed to address those limits. The impact if MINERvA is not approved will be a lack of our knowledge in neutrino cross sections which will limit the obtainable precision from the current and future high priority neutrino oscillation measurements.

D. Constraints and Assumptions

1. Operational Limitations

There are no foreseen operational limitations in regard to effectiveness, capacity, technology, or organization. If MINERvA were located in the MINOS near detector hall, then there is an adequate room in front of the MINOS near detector to accommodate the detector. There is a small possibility that neutrino or muon interactions in MINERvA could produce background in the MINOS near detector. This possibility is under study and if necessary, will be mitigated during the Approval of Alternative Selection and Cost Range.

2. Geographic, Organizational, and Environmental Limitations

Since the NuMI neutrino beam is the only suitable beam in existence, the MINERvA near detector will be sited on the Fermilab site in the MINOS near detector hall. This site will minimize any organizational and environmental concerns, since the MINOS near hall already houses an existing neutrino experiment utilizing similar technology.

3. Standardization and Standards Requirements

This project must conform to the applicable design and operational standards of the Fermi National Accelerator Laboratory (FNAL) facility and conform to the project management guidance offered by the DOE O 413.3, Project Management for the Acquisition of Capital Assets.

4. Environment, Safety and Health

All work at the FNAL site will be conducted under its DOE-approved Integrated Safety Management system. FNAL will comply with the requirements of the National Environmental Policy Act (NEPA).

5. Safeguards and Security

None of the work performed at the proposed detector will be classified, and no safeguard and security issues are foreseen during the design, construction, or operation phases. Access to the site will be controlled primarily to ensure worker and public safety and for property protection. Appropriate safeguard and security requirements will be implemented.

6. Project Interfaces and Interaction Requirements

The conditions and interfaces are fairly straightforward. The project would build a detector to operate at Fermilab in the NuMI beamline. All funding would be supplied from the DOE HEP program.

7. Affordability Limits on Investment

The preliminary Total Project Cost (TPC) range is \$8.5-\$11.0 million in then year dollars. Contributions from the National Science Foundation (NSF) or international collaborators are possible, but the current planning assumption is that all costs will be borne by the DOE HEP program.

8. Goals for Limitations on Recurring or Operating Costs

The cost of operating MINERvA is expected to be quite modest (i.e., approximately \$200k per year). It will use an existing and operating beamline for MINOS. The detector

hall is also existing and operating. Most routine maintenance and all calibration will be done by the scientific collaboration. A small number of Fermilab staff may be called upon as needed for problems that require special expertise. There will be the cost of consumables like power to operate the detector, spare parts, etc.

9. Legal and Regulatory Constraints or Requirements

The project will be in full compliance with all applicable federal, state, and local requirements. There are no known legal or regulatory issues that could impact the project.

10. Stakeholder Considerations

There are no significant stakeholder issues anticipated. The primary stakeholders in this project are those in the U.S. particle physics community who are pursuing neutrino physics.

11. Limitations Associated with Program Structure, Competition and Contracting, Streamlining, and Use of Development Prototypes or Demonstrations

Adequate technical resources are available at DOE laboratories, collaborating universities, and industry to plan and execute this project on a competitive basis.

E. Applicable Conditions and Interfaces

This is a relatively small project to be installed on an existing DOE site, the NuMI beamline at Fermilab. The majority of neutrinos will pass through the detector and there will be no effect on operations of the MINOS near detector in the same hall. Fermilab will be responsible for any coordination needed between the two experiments.

Installation of the MINERvA detector will disrupt MINOS near detector operations due to the need to operate the crane, cycle the power, perform welding, and conduct other activities that would affect the MINOS readout electronics. To minimize the effect on the MINOS program it should be scheduled to coincide with a regular accelerator maintenance shutdown.

F. Resource Requirements and Schedule

The following profile has been estimated for planning purposes only. Neither the profile nor the schedule has been approved at this time. The TPC range can be expected to change when the conceptual design is completed. Changes to the proposed schedule will impact the cost profile. The project would be funded as a Major Item of Equipment.

Estimated Funding

(Then Year M\$)

	Other Project Costs	Total Estimated Cost	Total Project Costs
FY 2006	1.0–1.5	-	1.0–1.5
FY 2007	1.5–2.0	-	1.5–2.0
FY 2008	-	4.0–5.0	4.0–5.0
FY 2009	-	2.0–2.5	2.0–2.5
Total:	2.5–3.5	6.0–7.5	8.5–11.0

The Other Project Costs are for research and development activities including development of the conceptual design report.

The following table shows the preliminary milestone schedule for Critical Decisions.

Preliminary Critical Decision Dates

CD-0 Approve Mission Need	2 nd quarter FY 2006
CD-1 Approve Alternative Selection and Cost Range	4 th quarter FY 2006
CD-2 Approve Performance Baseline	2 nd quarter FY 2007
CD-3 Approve Start of Construction	4 th quarter FY 2007
CD-4 Approve Start of Operations	4 th quarter FY 2009

G. Development Plan

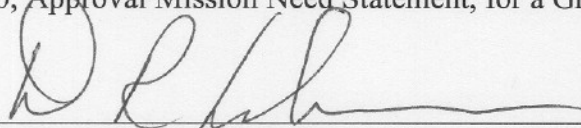
MINERvA's primary advantage will come from the intensity of the NuMI beam., however the detector will need to be assembled from smaller and more numerous detector elements than other existing neutrino experiments. This allows the individual particles produced in the neutrino interaction to be separated since they will be measured in separate detector elements.

The detector development strategy is to employ well-developed technology and to aggressively integrate value management principles in the design in order to accomplish its mission goals with a minimum of cost, risk and time to completion. Therefore, the R&D phase does not focus on development of new technologies, but rather the integration of many components which have been developed for other applications. As one example, the electronics being considered are based on an ASIC originally developed for the D0 Run IIb upgrade. This could result in significant cost savings, but requires testing to demonstrate that the borrowed ASIC design can meet the specifications. The diversity of detector systems required by a general-purpose neutrino interaction detector like MINERvA means there are many such components to test and integrate. Standard procedures to produce a conceptual design and then technical baseline will be followed.

Main INjector ExpeRiment v-A (MINERvA) CD-0 Review

Recommendations

The undersigned "Do Recommend" (Yes) or "Do Not Recommend" (No) approval of CD-0, Approval Mission Need Statement, for a Ground-Based Dark Energy Experiment.

 6/19/06

ESAAB Secretariat, Office of Project Assessment / Date

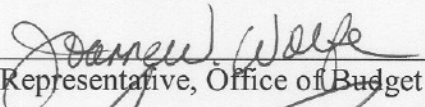
Yes ☒ No ☐

Representative, Non-Proponent SC Program Office/ Date

Yes ☐ No ☐

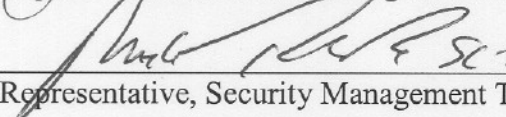
Representative, Environmental Safety and Health Division/ Date

Yes ☐ No ☐

 6/19/06

Representative, Office of Budget and Planning / Date

Yes ☒ No ☐

 SC-31 6-13-06

Representative, Security Management Team / Date

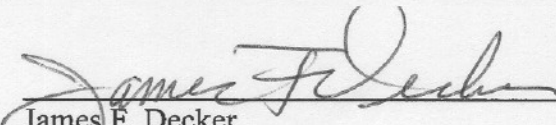
Yes ☒ No ☐

Representative, Grants and Contracts Division / Date

Yes ☐ No ☐

Representative, Laboratory Infrastructure Division/ Date

Yes ☐ No ☐


James F. Decker
Principal Deputy Director
Office of Science

6/19/06
Date

memorandum

DATE: FEB 2 2006

REPLY TO

ATTN OF :

Jay Hoffman

Director, Office of Program Analysis and Evaluation (CF-20)

SUBJECT: Mission Need Analysis for the Main Injector Experiment v-A (MINERvA) Project

TO: Raymond Orbach
Director, Office of Science

REF: Statement of Mission Need for the Main Injector Experiment v-A (MINERvA) Project

As required by DOE M 413.3-1, Project Management for the Acquisition of Capital Assets Manual, the Office of Program Analysis and Evaluation has completed an independent assessment (see attachment) of the referenced Mission Need Statement (MNS). Our recommendation is that the Director of the Office of Science approve the Mission Need Statement.

Should you need additional information, please contact me at (202) 586-6464 or your staff may contact Paul Haywood at (202) 586-9077.

Attachment: Analysis of Mission Need Statement for the Main Injector Experiment v-A (MINERvA) Project

cc:

Susan J. Grant, Chief Financial Officer

Patricia Hodson, Director, Office of Budget

Robert L. McMullan, Acting Director, Office of Engineering and Construction
Management

Robin Staffin, Associate Director of the Office of Science for High Energy Physics

Analysis of Mission Need Statement for the Main Injector Experiment ν -A (MINER ν A) Project

Sponsoring Organization: Office of High Energy Physics (HEP)
within the Office of Science (SC)

Background

Neutrino oscillation is a quantum mechanical phenomenon in which a neutrino of one type transforms into a neutrino of another type as it travels.¹ Oscillation is of theoretical and experimental interest, since it implies that the neutrino has mass which violates a fundamental premise of the Standard Model.

There are a large number of experiments trying to observe neutrino oscillations. Some rely on man-made sources like nuclear reactors or accelerators and others rely on "natural" sources such as solar neutrinos or neutrinos from cosmic-rays (otherwise known as atmospheric neutrinos). All of these neutrino oscillation experiments are complementary because they involve neutrinos of different energies traveling over different distances.

The probability that a particle interacts in a particular material is called a cross section. The only evidence that a neutrino was present in a detector is the shower of charged particles produced from a neutrino interaction with a proton or neutron in the detector. The detector traces the paths, or tracks, of charged particles and determines their energies.

Because the cross section in weak nuclear interactions is very small, neutrinos can pass through matter almost unhindered. For typical neutrinos produced in the sun (energy of a few MeV), it would take approximately one light year ($\sim 10^{16}$ m) of lead to block half of them. Therefore, detection of neutrinos can be extremely difficult, requiring large detection volumes or high intensity man-made neutrino beams. The cross section for a particle varies as a function of the neutrino beam energy and has been measured and published. However, the cross sections for low energy neutrinos (below 10 GeV) are difficult to measure and have not been studied with any reasonable accuracy.

To maximize the observation probability of neutrino oscillations, the Fermilab's Neutrinos at Main Injector (NuMI) facility is capable of producing a low energy beam of neutrinos in the 1 to 5 GeV range that travels 735 kilometers to the Main Injector Neutrino Oscillation Search (MINOS) far detector (located in northern Minnesota).² However, in its current configuration, the MINOS detector can not measure the neutrino cross sections because it can not identify the complete set of particles produced in a neutrino interaction.

Mission Need

The Office of Science's neutrino physics program is built upon precise knowledge of how neutrinos interact with matter. Currently, experimental errors on cross section data are large. The precise

¹ So far, three types of neutrino flavors have been observed. Each type of neutrino is related to a charged lepton (which gives the corresponding neutrino its name). Hence, the "electron neutrinos" (ν_e) are associated with the electron, and two other neutrinos are associated with other charged leptons: the muon neutrinos (ν_μ) and the tau neutrinos (ν_τ).

² There are actually two detectors in MINOS. The 'near' detector will act as a control, studying the beam as it leaves Fermilab, then the results will be compared with those from the 'far' detector (Minnesota) to see if the neutrinos have oscillated into electron or tau neutrinos during their journey.

Analysis of Mission Need Statement for the Main Injector Experiment ν -A (MINER ν A) Project

determination of neutrino cross sections is an essential ingredient in the interpretation of neutrino experiments. Moreover, cross section data potentially is capable of revealing exotic and unexpected phenomena, such as the existence of a neutrino magnetic dipole moment. Interpretation of atmospheric and long-baseline accelerator-based neutrino experiments, understanding the role of neutrinos in supernova explosions, and predicting the abundances of the elements produced in those explosions all require knowledge of neutrino cross sections. To address the mission need would require the fabrication of a high resolution neutrino detector capable of distinguishing explicit final states in the energy range of 0.5 to 3.0 GeV and measurement of cross-sections.

Policy Impact (goal cascade)

None, the scope of the effort is within the Department of Energy's General Goal 5: Provide world-class scientific research capacity needed to: ensure the success of Department missions in national and energy security; advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences; or provide world-class research facilities for the Nation's science enterprise.

Analysis of Project

There are two alternatives to improving the Office of Science's knowledge of cross sections:

Alternative 1:

The NuMI beam can be enhanced with a relatively small 2 meter by 2 meter detector that has higher sensitivities to the particles produced in a neutrino interaction. The detector would be placed upstream from the MINOS near detector. It would provide high quality cross section data with a Total Project Cost (TPC) of \$8.5 to \$11M.

Alternative 2

Since the NuMI beam is unique, there are no other existing neutrino beams which produce neutrinos at the same energy. A neutrino beam could be constructed at another high intensity proton accelerator such as the Spallation Neutrino Source. However, this would require construction of a new neutrino beam and detector hall. The TPC for this alternative is approximately \$200M.

Given the cost difference between the two alternatives, it is clear that Alternative 1 is the primary focal point of the MNS. The MNS must be derived from rigorous mission analysis that includes an analysis of current and forecasted mission capabilities in relationship to projected demand for services. It should be "need-oriented," and should not seek to justify a specific solution.

Cost and Schedule

The MINER ν A working group, a worldwide collaboration of scientists and institutions, has focused their support on the enhanced NuMI-based detector presented in alternative 1. Therefore, only the cost and schedule for alternative 1 will be presented. The preliminary Total Project Cost (TPC) range is \$8.5-\$11.0 million. Contributions from the National Science Foundation (NSF) or international collaborators are possible, but the current planning assumption is that all costs will be borne by the Department of Energy HEP program.

**Analysis of Mission Need Statement for the
Main Injector Experiment ν -A (MINER ν A) Project**
Estimated Funding
(Dollars in millions)

Funding Profile	Total Project Cost Range
FY 2006	1.0–1.5
FY 2007	1.5–2.0
FY 2008	4.0–5.0
FY 2009	2.0–2.5
Total:	8.5–11

The following table shows the preliminary milestone schedule for Critical Decisions.

Preliminary Critical Decision Dates

CD-0 Approve Mission Need	2nd quarter FY 2006
CD-1 Approve Alternative Selection and Cost Range	3 rd quarter FY 2006
CD-2 Approve Performance Baseline	2 nd quarter FY 2007
CD-3 Approve Start of Assembly	1st quarter FY 2008
CD-4 Approve Start of Operations	4 th quarter FY 2009

Issues: *Something that questions the basis of the mission need, and warrants not recommending approval of the MNS.*

None.

Observations: *Something that does not prevent issuing the approval recommendation for the MNS, however could impact the ability to carry out the project.*

Prior to CD-1, please consider the following points given the MINER ν A project is part of an overall neutrino program:

- How will this project and the overall neutrino program advance the Department's effort to actually achieve Strategic Goal 5?
- What are the programmatic trade-offs of funding this project (i.e., what does not get done)?
- What are the potential risks to HEP's neutrino program, the Office of Science, and the Department overall if this effort did not achieve the desired result?

Recommendation

The Program Secretarial Officer for this activity, the Director of Office of Science, should approve the Mission Need Statement.